

# FINAL TECHNICAL REPORT

## CSP - The 19th European Conference on Mathematics for Industry (ECMI 2016)

Grant number: N62909-16-1-2072

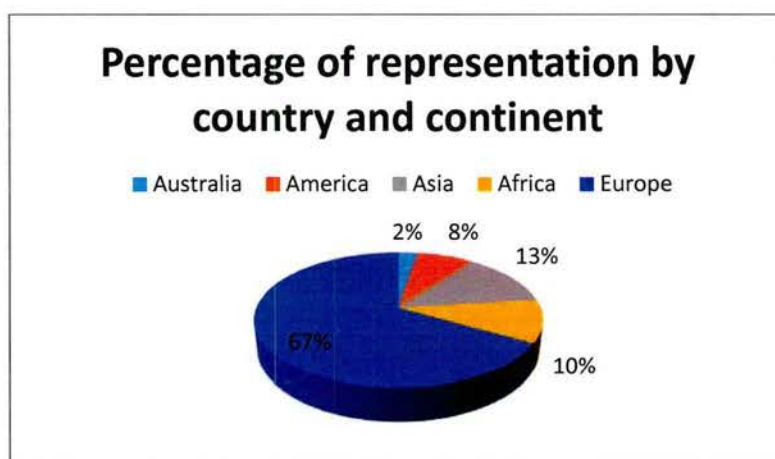
### Metrics

#### Registered participants

##### Number of individuals

##### Number of countries represented

348 researchers from 40 countries representing the five continents participated in ECMI 2016. Most of the attendees were from 26 European countries, but also from Australia, America (Canada, Mexico and USA), Africa (Nigeria, Sudan, Tanzania and Uganda) and Asia (China, India, Israel, Japan and The Philippines). Participants from Spain came up to 25% of the total.



The 6 more represented countries were:

Country	Number of Participants
Spain	85
Germany	68
France	29
Italy	22
Portugal	20
UK	18

## Institutional Participants

It is worth mentioning the support received by different institutions which send their representatives to participate in ECMI 2016.

During the **Opening Ceremony** we were lucky to count on J.M. Viaño, Rector of the *Universidade de Compostela*, D. Hömberg, President of the *European Consortium for Mathematics in Industry* and M. Varela, Director of the *Innovation Galician Agency of the Galician Government (Xunta de Galicia)*. Also at the table were A. Bermúdez de Castro, President of the Scientific Committee at ECMI2016 and P. Quintela, Chair of the Organizing Committee at ECMI2016.

In the **Closing Ceremony**, on the other hand, participated P. Quintela, Chair of the ECMI2016 Organizing Committee and D. Hömberg, President of the *European Consortium for Mathematics in Industry* as well as Peter Simon from *Eötvös Loránd University, Hungary* which will be the President of the Organising Committee for ECMI 2018.

From the 18 members of the **ECMI2016 Scientific Committee** the following 10 came to Santiago to attend the conference: Alfredo Bermúdez de Castro, chair. *Universidade de Santiago de Compostela (USC) and ITMATI*, Spain; Dietmar Hömberg, co-chair. President of ECMI. *Weierstrass Institute*, Germany; Stephen O'Brien, co-chair. *University of Limerick*, Ireland; András Bátkai. *Eötvös Loránd University*, Hungary; Emilio Carrizosa. *University of Seville*, Spain; Patrick Joly. *INRIA/CNRS*, France; Tuomo Kauranne. *Lappeenranta University of Technology*, Finland; Tim Myers. *Centre de Recerca Matemàtica*, Spain; Giovanni Russo. *University of Catania*, Italy; Barbara Wagner. *Weierstrass Institute*, Germany.

As well as all the above **Anni Hellman** Deputy Head of Unit *Directorate-General for Communications Networks, Content and Technology European Commission* participated at ECMI2016 in a session entitled *Maths in Horizon 2020 and beyond*.

## Grants

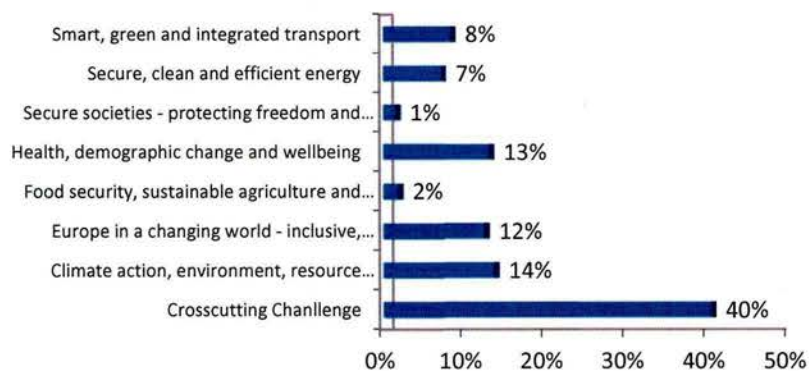
ECMI allocated 6 grants covering the cost of registration to participants from third-world countries such as India, the Philippines, Tanzania and Uganda. These grants were combined with the corresponding Campus Housing grant, funded by the Organizing Committee.

Furthermore, the Organizing Committee assigned three additional grants covering the cost of registration and also Campus Housing to participants from France and Spain.

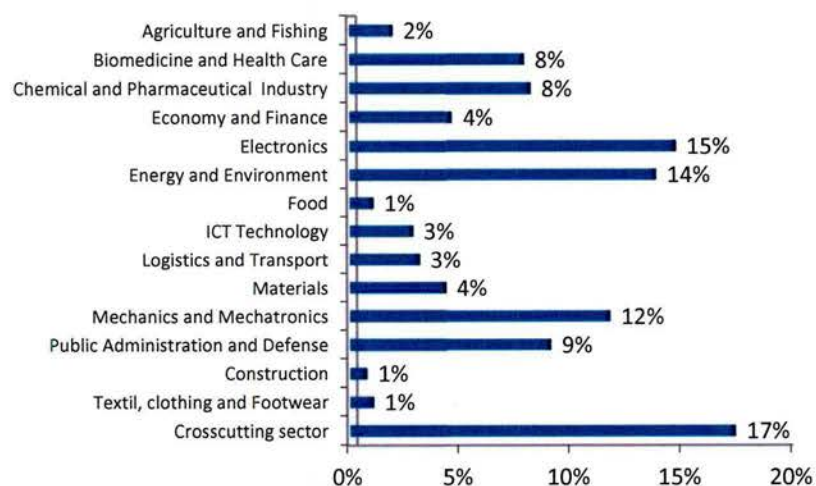
## Presentations

The ECMI 2016 scientific program had 10 plenary lectures, given by internationally renowned specialists in the field of industrial mathematics, and other 306 papers grouped in 39 mini symposiums and 19 sessions of contributed talks. In these communications, there were numerous cases of success of collaborations with industry and, specifically, there were 49 companies involved that, to satisfy their own demands, financed the work presented here.

### Distribution of Scientific Contributions per Societal Challenges H2020



### Distribution of Scientific Contributions per Industrial Sector





## Conference Program

Please see below a link to the detailed program which contains a summary of all the talks at ECMI2016: [http://www.usc.es/congresos/ecmi2016/?page\\_id=1982](http://www.usc.es/congresos/ecmi2016/?page_id=1982)

## Book of Abstracts of ECMI 2016

The Book of Abstracts of ECMI2016 has been published by the University Press of Santiago de Compostela in their collection *Cursos e Congresos*.

The book can be downloaded here and the DOI is: <http://dx.doi.org/10.15304/cc.2016.968>

## Number of invited speakers

10 invited speakers participated at ECMI 2016.

## Number of absentees

### Plenary speakers:

Karl G. Kempf from Intel Corporation, USA could not attend ECMI2016 as for security reasons his company did not allow him to fly to Spain.

### Participants:

7 registered participants could not attend ECMI2016 in the end due to reasons such as personal issues (pregnancy, accident etc.) or lack of visa.

## Contact information (names, organization, email addresses, phone numbers, presentation titles)

The invited speakers were:

- **Toufic Abboud.**  
Organization: IMACS, XTEC, École Polytechnique, France.  
Email address: [abboud@imacs.polytechnique.fr](mailto:abboud@imacs.polytechnique.fr)  
Phone Number: +33 1 69 33 89 80 (89 91)  
Plenary talk title: *Boundary Element Method for Electromagnetic Compatibility Problems.*  
This research was partially funded by Airbus.
- **S. Jon Chapman.**  
Organization: University of Oxford, UK.  
Email address: [chapman@maths.ox.ac.uk](mailto:chapman@maths.ox.ac.uk)  
Phone Number: +44 1865 270507  
Plenary talk title: *Mathematical modelling of lithium ion batteries.*

- **Linda J. Cummings.**  
 Organization: New Jersey Institute of Technology, USA.  
 Email address: [linda.cummings@njit.edu](mailto:linda.cummings@njit.edu)  
 Phone Number: +1 973-596-5479  
 Plenary talk title: *Mathematical modeling of membrane filtration.*  
 This research was partially funded by Pall Corporation.
- **Luca Formaggia.**  
 Organization: Politecnico di Milano, Italy.  
 Email address: [luca.formaggia@polimi.it](mailto:luca.formaggia@polimi.it)  
 Phone Number: +39 02 23994605  
 Plenary talk title: *Geometrical multi-scale modeling of liquid packaging system: an example of scientific cross-fertilization.*  
 This research was co-funded by Tetra Pak Packaging Solutions S.p.A.
- **Wenceslao González.**  
 Organization: Universidade de Santiago de Compostela, Spain.  
 Email address: [wenceslao.gonzalez@usc.es](mailto:wenceslao.gonzalez@usc.es)  
 Phone Number: +34 8818 13204  
 Plenary talk title: *Semiparametric prediction models for variables related with energy production.*
- **Miguel Ángel Herrero.**  
 Organization: Complutense University of Madrid, Spain.  
 Email address: [herrero@mat.ucm.es](mailto:herrero@mat.ucm.es)  
 Phone Number: +34 91 394 4405  
 Plenary talk title: *Emergent behaviour in T-cell immune response.*
- **Barbara Kaltenbacher.**  
 Organization: Alpen-Adria Universität, Klagenfurt, Austria.  
 Email address: [Barbara.Kaltenbacher@aau.at](mailto:Barbara.Kaltenbacher@aau.at)  
 Phone Number: +43 463 2700 3120  
 Plenary talk title: *Mathematics of Nonlinear Acoustics: Modeling, Numerics, Optimization.*
- **Panos M. Pardalos.**  
 Organization: University of Florida, USA.  
 Email address: [pardalos@ise.ufl.edu](mailto:pardalos@ise.ufl.edu)  
 Phone Number: +1 352-294-7718  
 Plenary talk title: *Optimization, Modeling, and Data Sciences for Energy Systems.*
- **Koby Rubinstein.**  
 Organization: Technion, Israel & Indiana University, USA.  
 Email address: [koby@tx.technion.ac.il](mailto:koby@tx.technion.ac.il)  
 Phone Number: +972-4-8294096  
 Plenary talk title: *The Weighted Least Action Principle: Theory and Applications.*
- **Joseph M. Teran.**  
 Organization: University of California, Los Angeles, USA.  
 Email address: [jteran@math.ucla.edu](mailto:jteran@math.ucla.edu)  
 Phone Number: +1 310 206-0048  
 Plenary talk title: *Snow Business: Scientific Computing in the Movies and the Classroom.*



## Awards (identify name of award, recipient name)

### **Anile-ECMI Prize for Mathematics in Industry**

The Anile-ECMI Prize for Mathematics in Industry was established to honour Professor Angelo Marcello Anile (1948-2007) of Catania, Italy and consists of a prize of 2.500€ and an invitation to give a talk at an ECMI conference.

The prize is given to a young researcher for an excellent PhD thesis in industrial mathematics presented at a European university in the period 2014-2016. The 2016 Anile-ECMI Prize for Mathematics in Industry was awarded to [Francesc Font](#) from the University of Limerick. Francesc presented at ECMI 2016 a talk entitled *Influence of substrate melting on the laser-induced dewetting of nanothin films* which was part of minisymposium *MS03: Moving boundary problems in industrial applications*.

#### **Summary of his talk:**

Dewetting of thin nanoscale metallic films has shown promise as a self-assembly process for synthesizing large-area correlated nanoparticle ensembles. This process involves laser irradiating a metal nanothin film sitting on a substrate with lower thermal conductivity. After laser irradiation, the temperature of the metal, initially in a solid state, raises over the melting point and the metal becomes a liquid. The thin liquid layer is unstable and so breaks up into droplets. In the absence of further heating the droplets subsequently solidify. Experimental observations suggest that the high temperatures reached during laser irradiation lead to partial melting of the substrate, which presumably affects the dewetting behaviour of the metal film. In this talk, he presented a one-dimensional model describing the heat transfer and phase change of the metal/substrate set up after laser irradiation and discuss the possible effects of a molten substrate in the dewetting process.

### **Hansjörg Wacker Memorial Prize**

The Hansjörg Wacker Memorial Prize was established in memory of ECMI's founding member Hansjörg Wacker (1939-1991), who was Professor of Numerical Mathematics at the Johannes Kepler University, Linz. The prize is jointly funded by ECMI and by a consortium of institutions from Linz which comprise the Industrial Mathematics Institute and the Institute of Computational Mathematics of Johannes Kepler University, and the Johann Radon Institute for Computational and Applied Mathematics of the Austrian Academy of Sciences. It consists of a prize of 1.000€ and the invitation to attend an ECMI conference presenting his/her project as a contributed talk.

The prize is awarded for the best mathematical dissertation at the Masters level on an industrial project written by a student from an ECMI institution. The 2016 Hansjörg Wacker Memorial Prize was awarded to [Elisa Riccietti](#) from the *Università degli Studi Firenze*. Elisa presented at ECMI 2016 a talk entitled *Numerical methods for optimization problems: an application to energetic districts* part of the Contributed Talk *CT05: Optimization problems*.

#### **Summary of her talk:**

The electric system has been experiencing a dramatic evolution in the last years, mainly driven by the massive spread of renewable energies and by the increasing attention to energy

efficiency and emission reduction. A much smarter electricity system is required, in which each customer would be able to support system stability by means of active load response, as well as by using generators and energy storage systems that may be localised at their premises.

Within this framework, Enel Research and Innovation has developed a software package to optimize the energy resources management of industrial districts, with the aim of minimizing the customer energy bill. Taking into account real time information on customer energy needs and production, and forecasts on energy requirements and availability at customer, and on energy market prices in the next hours, a cost function is built that should be minimized.

Here we focus on the solution of the arising constrained optimization problem. We describe the two solvers that have been employed for its solution: a Sequential Linear Programming, and a Particle Swarm Optimization. The performance of the two solvers is compared on realistic models of industrial districts and on a real district. It is shown that the use of the package would allow savings in the energy bill, with respect to the standard paradigm in which energy is produced when required by loads.

## Electronic copy of presentations (restricted distribution: only within ONR)

The invited speakers do not allow us to release the presentations and therefore we have added below a summary of their talks as it appears on the ECMI 2016 website. Some speakers, however, allowed us to record their talks and we have added a link below accordingly.

Summary of the talks delivered by the invited speakers:

- **Toufic Abboud.** *IMACS, XTEC, École Polytechnique, France.*  
Link to speaker: [http://www.usc.es/congresos/ecmi2016/?page\\_id=1631](http://www.usc.es/congresos/ecmi2016/?page_id=1631)  
Plenary talk title: Boundary Element Method for Electromagnetic Compatibility Problems  
Summary: Electromagnetic immunity problems represent a major issue in aeronautic industry and concern a wide variety of phenomena and threats: Lightning Indirect Effects (LIE), High-Intensity Radiated Fields (HIRF), antenna coupling, wireless networks etc. The design of electromagnetic protection is a difficult task with multiple constraints: weight, cost, delays, life-cycle management etc. The extensive use of lightweight composite and smart materials, the increasing complexity of onboard systems, the uncertainties (related to material properties, manufacturing, ageing etc.) make the problem very complex. It is essential to boost simulation capabilities in order to safely introduce innovations in the aircraft design and move to robust design and margin management.

These industrial needs pose significant challenges for numerical modelling:

- deal with a very large frequency band, starting from DC up to several Gigahertz. For time domain solvers, that represents a huge number of time steps, dispersion and late time instability issues, while frequency domain solvers may be subject to



- instability in the low frequency regime. Loop-tree decomposition can be used for this issue but it is notoriously difficult to apply for multi-domain problems.
- estimate and implement reduced models (wires, slots, equipments, generators etc.) in 3D solvers.
- handle multi-partner collaborative simulation and design optimisation: domain decomposition techniques and ability to couple 3D-models with complex nonlinear circuit models of equipments.
- efficiently handle transmission conditions (including skin effect) and evaluate low levels of currents and fields inside closed cavities.
- take into account geometric and data singularities. A combination of a priori and adaptive meshing procedures based on a posteriori error estimates is required for robust (engineer independent) simulations.
- reliable and efficient model reduction for parametric studies and uncertainty management.
- model size (number of degrees of freedom) requires efficient fast and parallel solvers.

We show how these issues can be addressed by a frequency domain integral equation method. In particular, we show how a multi-trace BEM formulation can solve both the low level in cavities and the low frequency instability issues. We present some industrial numerical examples.

- **S. Jon Chapman.** *University of Oxford, UK.*

Link to speaker: [http://www.usc.es/congresos/ecmi2016/?page\\_id=828](http://www.usc.es/congresos/ecmi2016/?page_id=828)

Plenary talk title: Mathematical modelling of lithium ion batteries

Summary: A framework is presented for modelling the physical and chemical dynamics of a lithium-ion battery using the method of multiple scales to derive a macroscopic model from a detailed electrode microstructure. The result is a porous electrode model similar in flavour to the standard model of Newman, but in which the macroscopic parameters such as permeability are directly related to the micro- scopic electrode structure.

The model includes both electrokinetic transport phenomena and mechanical deformation due to electrode swelling, and is thus able to predict local mechanical stresses. These in turn may lead to cracking with a resulting degradation of battery performance.

Recording of the talk:

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- **Linda J. Cummings.** *New Jersey Institute of Technology, USA.*

Link to speaker: [http://www.usc.es/congresos/ecmi2016/?page\\_id=1084](http://www.usc.es/congresos/ecmi2016/?page_id=1084)

Plenary talk title: Mathematical modeling of membrane filtration

Summary: Membrane filters – essentially, thin sheets of porous medium which act to remove certain particles suspended in a fluid that passes through the medium – are in widespread industrial use, and represent a multi-billion dollar industry in the US alone. Major multinational companies such as W.L. Gore & Associates, and Pall Corporation,



manufacture a huge range of membrane-based filtration products, and maintain a keen interest in improving and optimizing their filters. Membrane filtration is used in applications as diverse as water purification; treatment of radioactive sludge; various purification processes in the biotech industry; the cleaning of air or other gases; and beer clarification. While the underlying applications and the details of the filtration may vary dramatically (gas vs liquid filtration; small vs large particle removal; slow vs fast throughput; rigid vs deformable particles), the broad engineering challenge of efficient filtration is the same: to achieve finely-controlled separation at low power consumption.

The desired separation control is to remove only those particles in a certain size range from the input flow (often referred to as “feed”); and the obvious resolution to the engineering challenge would appear to be: use the largest pore size and void fraction consistent with the separation requirement. However, these membrane characteristics (and hence the filter’s behavior and performance) are far from constant over its lifetime: the particles removed from the feed are deposited within and on the membrane filter, fouling it and degrading the performance over time. The processes by which this fouling occurs are complex, and depend strongly on several factors, including: the internal structure of the membrane; the flow dynamics of the feed solution; and the type of particles in the feed (the shape, size, and chemistry affects how they are removed by the membrane).

Though the fouling literature is extensive, a complete and coherent predictive framework that can realistically describe all fouling modes of a membrane filter is still lacking. A recent review by Iritani concludes by noting that “. . . further development of simple yet effective mathematical models for elucidating the complicated pore-blocking phenomena in membrane filtration would be highly desirable for guiding decisions on the optimal choice of the membrane and membrane-cleaning strategy in industrial use.”

In this talk we describe some of our recent and ongoing work on first-principles modeling of membrane filtration and fouling. Particular emphasis is paid to how membrane filter design (e.g. permeability gradients across the membrane) can significantly affect filtration efficiency, as measured by (i) total throughput over a filter lifetime, and (ii) proportion of particles removed from the feed.

Recording of the talk:

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- **Luca Formaggia.** *Politecnico di Milano, Italy.*  
Link to speaker: [http://www.usc.es/congresos/ecmi2016/?page\\_id=1070](http://www.usc.es/congresos/ecmi2016/?page_id=1070)  
Plenary talk title: Geometrical multi-scale modeling of liquid packaging system: an example of scientific cross-fertilization.  
Summary: Geometrical multi-scale modeling that comprises the coupling of differential models operating at different spatial dimensions (3D, 1D, 0D, for instance) have proved very successful in the simulation of the human cardiovascular system.

The long-lasting experience in such type of modeling is here exploited in a very different context that is the numerical modeling of packaging systems for liquid food products. Indeed, this application shares many common features with the flow in the cardiovascular system, in particular strongly coupled fluidstructure interactions (FSI), the presence of flow in pipes coupled with both complex three-dimensional geometries and lumped (zero-dimensional) models. The final objective of this numerical investigation is the development of an efficient tool for the simulation of the pressure wave propagation through the different components of the packaging system.

In this talk, we present a family of models that can be applied to this type of problems, their numerical implementation and numerical results that show the effectiveness of the procedure adopted for the solution of a real industrial application.

The work is an example of contamination of ideas between different applications and is the result of a fruitful collaboration among academic and industrial researchers.

- **Wenceslao González.** *University of Santiago de Compostela.*  
Link to speaker: [http://www.usc.es/congresos/ecmi2016/?page\\_id=1088](http://www.usc.es/congresos/ecmi2016/?page_id=1088)  
Plenary talk title: Semiparametric prediction models for variables related with energy production.  
Summary: The “Semiparametric Statistical Inference” was object of study in last decades with new methodological advances and nice applications.

In this talk, we present different semiparametric dynamic regression models designed for the prediction of variables related with energy production. Mainly, with variables associated with the effects of the pollution and the demand of energy.

In the first part of the talk, we review different models developed throughout the years thanks one extensive collaboration between the Department of Statistics and Operation Research of the University of Santiago de Compostela and Endesa Generation, S.A., in Spain. Starting with one first study (García-Jurado et al (1995)), several predictive methods were considered for the forecasting of future values of SO<sub>2</sub> and NO<sub>x</sub>. Neural Networks and models with functional predictors are examples of the different developed statistical tools, which were included in one “Supplementary Control System of Air Quality” for one power station in the northwest of Spain.

In the second part of the talk the revision is related with models for variables associated to the electricity consumption. A new step-wise method using one combination of the modern “distance correlation” (Szekely et al. (2007)) with selection criteria of general functional covariates to be used in generalized additive models (Febrero-Bande and González-Manteiga (2013)) is given.

Recording of the talk:

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- **Miguel Ángel Herrero.** *Complutense University of Madrid.*  
Link to speaker: [http://www.usc.es/congresos/ecmi2016/?page\\_id=1072](http://www.usc.es/congresos/ecmi2016/?page_id=1072)  
Plenary talk title: Emergent behaviour in T-cell immune response.  
Summary: Humans are able to implement efficient immune responses to address pathogenic challenges. It is truly remarkable that such actions arise out of individual decisions made by each single cell according to information provided by her immediate neighbourhood as interpreted through her membrane receptors only. In particular, no central coordination organ supervises the resulting population behaviour. Moreover, the number of individual choices for the involved cells is rather limited, and usually reduces to deciding between cell division, cell death by apoptosis and differentiation into a new type of cell. In spite of the local nature of any such decision, a coordinated response is observed at the population level, which can be seen as an emergent property of the underlying dynamics.

In this lecture a particular example of such emergent behaviour, namely T-cell mediated immune response to acute infection, will be discussed. More precisely, a minimal model will be presented to explain an intriguing feature of such response, namely the onset of a delayed clonal contraction. This term refers to the fact that a) effector T-cells continue to be produced in high numbers well after the pathogen numbers have become negligible, and b) later on, most of the large T-cell population thus generated is eliminated by apoptosis, except for a small percentage of already trained individuals that are preserved as memory cells. These will thus be in place to mount a response, should a similar pathogenic invasion takes place in a near future. Interestingly, a similar approach allows to discuss possible mechanisms for T-cells to tell friend from foe when facing antigenic stimuli, be it produced by their own body or having an external origin instead. To conclude, a number of generalizations and future research directions will be discussed.

Recording of the talk:

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- **Barbara Kaltenbacher.** *Alpen-Adria Universität, Klagenfurt, Austria.*  
Link to speaker: [http://www.usc.es/congresos/ecmi2016/?page\\_id=1080](http://www.usc.es/congresos/ecmi2016/?page_id=1080)  
Plenary talk title: Mathematics of Nonlinear Acoustics: Modeling, Numerics, Optimization.  
Summary: High intensity ultrasound is used in numerous medical and industrial applications ranging from lithotripsy and thermotherapy via ultrasound cleaning and welding to sonochemistry. We will highlight several mathematical and computational aspects related to the relevant nonlinear acoustic phenomena.

Physical and mathematical modeling of high intensity ultrasound and generally of nonlinear acoustics is still an ongoing process and a field of active research. The classical models of in this context are nonlinear wave equations exhibiting potential degeneracy as well as strong damping. Taking into account higher order effects leads to third or fourth order PDEs. An additional important issue is the coupling of acoustics to other



physical fields, e.g., when focusing by a linearly elastic silicone lens immersed in the nonlinearly acoustic fluids, as typical for a widely used class of lithotripsy devices. This is joint work with Irena Lasiecka (University of Memphis), Rainer Brunnhuber (Alpen-Adria- Universität Klagenfurt), Vanja Nikolic (TU München) as well as Petronela Radu (University of Nebraska at Lincoln).

In the simulation of high intensity ultrasound, a particular challenge due to nonlinearity and the presence of different wave lengths is efficient and robust time integration. For this purpose, a promising approach are operator splitting techniques exploiting the intrinsic structure of the equations. The original second or third order in time evolution equations are split into simple subproblems that can be solved by standard methods or even explicitly. Combination of such appropriately weighted subproblems by exponential operator splitting schemes leads to highly efficient time integration methods. This is joint work with Vanja Nikolic (TU München) and Mechthild Thalhammer (University of Innsbruck).

Strictly speaking, acoustic sound propagation takes place in full space  $\mathbb{R}^d$ , or at least in a domain that is typically much larger than the region of interest  $\Omega$ . To restrict attention to a bounded domain  $\Omega$ , e.g., for computational purposes, artificial reflections on the boundary  $\partial\Omega$  have to be avoided. This can be done by imposing so-called absorbing boundary conditions ABC that induce dissipation of outgoing waves. Here it will turn out to be crucial to take into account nonlinearity of the PDE also in these ABC. This is joint work with Igor Shevchenko (Imperial College London).

Finally, we will discuss some practically relevant optimization problems in the context of nonlinear acoustics applications in lithotripsy. The optimal choice of ultrasound excitation via piezoelectric transducers leads to a boundary control problem; focusing high intensity ultrasound by a silicone lens requires shape optimization. For both problem classes, we will discuss the derivation of gradient information in order to formulate optimality conditions and drive numerical optimization methods. This is joint work with Christian Clason (University of Duisburg-Essen), Vanja Nikolic (TU München), and Gunther Pechl (University of Graz).

Recording of the talk:

[https://193.144.34.42/videos/video/3935/?access\\_token=shr00000039354437485691304581617079376584513](https://193.144.34.42/videos/video/3935/?access_token=shr00000039354437485691304581617079376584513)

- **Panos M. Pardalos.** *University of Florida, USA.*

Link to speaker: [http://www.usc.es/congresos/ecmi2016/?page\\_id=1074](http://www.usc.es/congresos/ecmi2016/?page_id=1074)

Plenary talk title: Optimization, Modeling, and Data Sciences for Energy Systems.

Summary: For decades, power systems have been playing an important role in humanity. Industrialization has made energy consumption an inevitable part of daily life. Due to our dependence on fuel sources and our large demand for energy, power systems have become interdependent networks rather than remaining independent energy producers. This talk focuses on the problems arising in energy systems as well as recent advances in optimization, modeling, and data sciences techniques to address



these problems. Among the topics to be discussed are emission constrained hydrothermal scheduling, electricity and gas networks expansion, as well as reliability analysis of power grid.

- **Koby Rubinstein.** *Technion, Israel & Indiana University, USA.*

Link to speaker: [http://www.usc.es/congresos/ecmi2016/?page\\_id=1076](http://www.usc.es/congresos/ecmi2016/?page_id=1076)

Plenary talk title: The Weighted Least Action Principle: Theory and Applications.

Summary: The Optimal Transport problem, first formulated by Monge in 1781, has become a central theme in modern analysis. It involves fascinating mathematics, poses great computational challenges, and has already met with many applications ranging from fluid mechanics, to economy and to medicine.

In my talk I review recent developments in this theory from an applied mathematician point of view. After introducing the key concepts, I discuss recent theoretical advances motivated by fundamental questions in wave propagation.

In particular I explain the connection between optimal transport and geometric optics for dispersive waves, and extensions of the classical optimal transport theory to dissipative systems and to singular solutions.

Finally, I review applications to practical problems in optics, including phase reconstruction and beam shaping.

- **Joseph M. Teran.** *University of California, Los Angeles, USA.*

Link to speaker: [http://www.usc.es/congresos/ecmi2016/?page\\_id=1078](http://www.usc.es/congresos/ecmi2016/?page_id=1078)

Plenary talk title: Snow Business: Scientific Computing in the Movies and the Classroom.

Summary: New applications of scientific computing for solid and fluid mechanics problems include simulation of virtual materials for use in movie special effects and virtual surgery. Both disciplines demand physically realistic dynamics for materials like water, smoke, fire, and brittle and elastic objects. Separate new algorithms are required for each area. Teran will speak about the simulation techniques required in these fields and will share some recent results including: simulated surgical repair of biomechanical soft tissues; extreme deformation of elastic objects with contact; high resolution incompressible flow; and clothing and hair dynamics. He will also discuss a new algorithm used for simulating the dynamics of snow in Disney's animated feature film, "Frozen".

Joseph Teran's talk was part of a special event designed as an outreach activity of the mathematical technology in the audio-visual world under the ECMI 2016 Congress: *The mathematical way to the Oscars*. The event took place at the Pazo de Ramirás, Auditorium ABANCA, Santiago de Compostela with the below format:

- **Chairman:** Jorge Mira Pérez. University of Santiago de Compostela. Professor of Electromagnetism and Science Communicator.
- **Main conference** *Snow business: Scientific computing in the movies and the classroom*. Conference of Joseph M. Teran. University of California, Los Angeles, USA.

- **Panel discussion:** Joseph M. Teran; Xenxo Álvarez from The Gearing / Ottiplanet, *Trends in character development for animation and videogames*; Ignacio Vargas from Next limit Technologies, *High Quality physics in game cinematics*.

## Conclusions

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### Most significant advance reported

The ECMI 2016 exceeded by far the expectations of the Organizing Committee and therefore marked a before and after in the conferences of industrial mathematics both nationally and internationally.

Significant milestones at the scientific and / or technological level of the ECMI2016:

- The conference showed the extent to which collaboration with industry has led to the opening of new lines of research in the field of mathematics and its reflection in publications with international impact as well as in the development of doctoral theses.
- Introduced existing infrastructures that have contributed to enhance the transfer of mathematical knowledge to the productive sector.
- Presented postgraduate programs oriented to training in mathematical techniques with demand in the company.
- Suggested solutions to transfer mathematical technology to the productive fabric, to society, and especially to companies and public administrations.
- It showed the experience of the different research groups in the development of solutions adapted to the business world, with the aim of introducing innovations and improvements through the application of the latest and most demanded mathematical technologies.
- The impact of mathematics on the innovations of key technologies was explained and the development of new modeling, simulation and optimization tools was encouraged.
- New international alliances were opened between research groups to jointly address major problems of concern to improve the quality of life, reduce resolution costs, shorten development times, reduce global energy demand and minimize environmental impact.
- The work of European scientists was coordinated to collaborate from mathematics in the construction of a more competitive and innovative Europe.

### Most significant challenge to progress

The math-in network, one of the organizers of ECMI 2016, has established partnerships following the conference in order to apply to calls of the EU Horizon 2020 program. The partnerships with countries such as Germany, France, Norway, UK, the Netherlands etc. will deal with subjects presented at the conference and which are in demand nowadays: energy networks, batteries and water treatment networks.



Due to the networks created at ECMI2016 there has already been a submission to the European call “Green Vehicles” in which the Spanish Company Repsol acts as a leader of the proposal.

## Path forward

International events focused on leading industrial sectors will be organized in order to open new collaborations on issues of industrial interest.

## Future plan for this conference

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During the closing ceremony of the successful ECMI 2016 conference in Santiago de Compostela the next ECMI conference was announced by Dietmar Hömberg, President of ECMI. ECMI2018 will be held on 18-22 June 2018 in Budapest (Hungary) with Péter L. Simon, secretary-general of the János Bolyai Hungarian Mathematical Society and Professor at Eötvös Loránd University acting as President of the Organizing Committee.

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14. ABSTRACT ECMI conferences, promoted by the European Consortium for Mathematics in Industry, aim to enforce the interaction between academy and industry, leading to innovation in both fields. 348 researchers from 40 countries (5 continents) participated in ECMI2016 (13-17 June 2016). 306 communications, 39 minisymposiums, 19 sessions of contributed talks & 10 invited speakers contributed to its success. The most represented subjects were: Electronics (15%), Energy & the Environment (14%) and Mechanics (12%). During ECMI2016 a dissemination event entitled "The Mathematical Way to the Oscars" took place. Its aim was to show that mathematics help developing special effects for movies & video games.						
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